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REPEATED ACQUISITION OF CONDITIONAL DISCRIMINATIONS[1]

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A new technique was developed to study the repeated acquisition of conditional discriminations. Using a discrete trial procedure, pigeons were required to learn during each session a different two-member chain of conditional discriminations. Key color and geometric forms were used as stimuli. After the pigeons had reached a steady state of relearning (40 to 60 sessions), the technique was used to investigate variables that have previously been shown to affect the repeated acquisition of response sequences. Various (0 to 90 seconds) durations of timeout for errors were investigated in Experiment I. The stimulus change associated with a timeout, rather than its duration, was found to be the critical variable in acquisition of the discrimination. Extended training on a single chain was found to reduce total errors across sessions in Experiment II. Extended training (three sessions) did not, however, change the pattern of within-session error reduction. In some cases, extended training facilitated acquisition of a partially reversed discrimination. In Experiment III, color rather than chain position was found to control behavior, for three of the four birds, as the second stimulus dimension in the conditional situation. The results of these experiments replicate and extend previous findings concerning some of the variables that affect the repeated acquisition of response sequences.

Key words: conditional discrimination, repeated acquisition, key peck, pigeons

Boren (1963) described a procedure whereby the acquisition of response sequences may be repeatedly investigated using a single organism as its own control. Variations on this basic procedure have resulted in the investigation of a variety of variables that affect the acquisition of such behavior. (*e.g.,* Mackay and Brown, 1971; Schrot, Boren, and Moerschbaecher, 1976; Sidman and Rosenberger, 1967; Thompson, 1975). In these procedures, a subject is required to respond in a predetermined sequence on some number of operanda with a reinforcer delivered at the end of the sequence. For example, Boren and Devine (1968) used 12 levers arranged in four groups of three. Each session, the subject's task was to acquire a new four-response chain, sequentially responding on one lever in each of the four groups. By changing the sequence of correct responses from session to session, this procedure was used to produce a steady state of relearning.

The present study represents a procedural extension of this technique to the study of the acquisition of conditional discriminations. In this paper, the term conditional discrimination is used as defined by Blough (1956): "responding is not controlled by a single stimulus entity, but by two stimuli taken together . . ." (p. 335). After establishing the initial baseline, in which a different chain of conditional discriminations was repeatedly acquired each session, variables that have previously been shown to affect the repeated acquisition of response sequences were investigated. This was done simply to determine if variables such as (1) timeout duration, (2) extended training, and (3) a tandem schedule would affect behavior in this new procedure in a manner similar to that previously reported.

EXPERIMENT I: EFFECT OF TIMEOUT

The purpose of Experiment I was to determine the effect timeout duration has on the repeated acquisition of conditional discriminations. Boren and Devine (1968) investigated

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how the duration of timeout, contingent on errors, affects the acquisition of response sequences. They found error levels were lowest when a timeout of any duration was compared to no timeout. No difference in the number of errors, however, was found between the various timeout durations (1 sec to 4 min). Whether or not similar effects might be found in another procedure of repeated acquisition, where the discrimination being learned was conditional, was of prime interest in Experiment I.

Method

Subjects

Four experimentally naive Silver king pigeons were maintained at approximately 80% of their free-feeding weights throughout the experiment. Water and grit were continuously available in a subject's home cage.

Apparatus

The experimental space was a chamber measuring 43 by 61 by 42 cm, ventilated by a fan mounted on the rear wall opposite the response panel. The response panel contained four keys spaced to form a rectangle 10.5 by 15 cm; another key was located in the center of the rectangle. Only the center and lower two keys were used. A Grason-Stadler (#15b) in-line stimulus projector, mounted behind each key, projected colors, geometric forms, or combinations of both on the key. A relay mounted behind the panel clicked after each response. The 6- by 6-cm feeder aperture was located in the middle of the response panel 6 cm above the floor; the feeder was illuminated with white light during the reinforcement cycle. Masking noise was present in the experimental room at all times. Programming and data-collection instruments were located in an adjacent room.

Procedure

The procedure was a two-link chain of conditional discriminations. Four geometric forms (triangle, circle, square, and cross), which could be superimposed on either a red or green background, served as stimuli. The red background was associated with the first link and green with the second link of the chain. The geometric forms superimposed on these colors served as discriminative stimuli for either a right- or left-key response. A diagram of the procedure is shown in Figure 1.

For convenience, a response on the center key was used to designate the start of a trial, even though there was no "intertrial interval", as conventionally defined. At the start of each trial, a stimulus (*e.g.*, triangle red) was displayed on the center key. A peck on the center key illuminated the two side keys white. At this point, the subject's task was to peck one of the two side keys, depending on the stimulus displayed on the center key. For each link in the chain, a single form superimposed on a particular color (red or green) was the discriminative stimulus for a left-key response. A right-key response to that stimulus was incorrect. Any other geometric form in combination with that color was a discriminative stimulus for a right-key response. A left-key response was incorrect for these stimuli. There were, therefore, two types of correct and incorrect responses. A response on either side key terminated the trial and turned the side keys off.

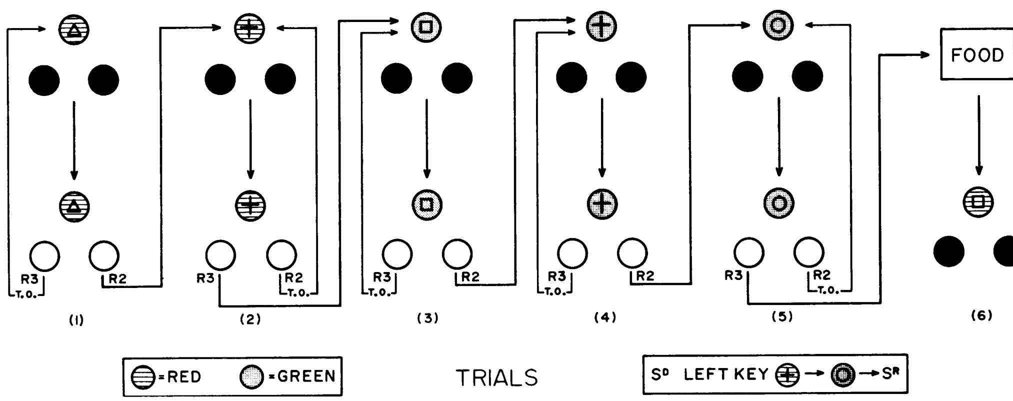

Fig. 1. An example of the conditional discrimination procedure showing five possible trials.

All correct responses resulted probabilistically (P = 0.75) in a change of the geometric form superimposed on the background color. That is, on any given trial following a correct response, the occurrence of each form was equiprobable. Correct left-key responses advanced the chain to the next link. The first correct response on the left key changed the background color from red to green (see R3 on Trial 2 in Figure 1). The second correct response on the left key was reinforced with grain (see R3 on Trial 5 in Figure 1). Correct right-key responses did not advance the chain to the next link (*i.e.*, change the background color). Correct responses made on this key resulted only in a different geometric form superimposed on the background color and in a brief illumination of the feeder (see R2 on Trials 1, 3, and 4 of Figure 1).

Incorrect responses made on either the left or right key resulted in a timeout, during which the chamber was dark (*e.g.*, R3 on Trial 1 and R2 on Trial 2 of Figure 1). Following a timeout, the same stimulus was presented on the subsequent trial(s) until a correct response was made (correction procedure).

The repeated acquisition (*i.e.*, learning) aspect of the procedure was generated by changing the discriminative stimuli for a left-key response from session to session. Each session, the two colors were scheduled in the same chain position (red followed by green). However, the geometric forms in combination with these colors, which set the occasion for a left-key response, were changed from session to session. For example, as shown in Figure 1, during one session the left-key discriminative stimuli were a cross on a red background (first link) and a circle on a green background (second link). During this same session, a right-key response was correct for all other geometric forms in combination with either color. For the next session, the correct left-key stimuli were a triangle on a red background and a square on a green background. Any other forms in combination with either color were discriminative stimuli for a right-key response. The forms were arranged as discriminative stimuli for a left-key response across sessions in the following sequence: triangle-circle, square-cross, circle-triangle, cross-square, circle-cross, square-triangle, cross-circle, triangle-square, cross-triangle, square-circle, triangle-cross, and circle-square.

In summary, during each session the subject acquired a different conditional discrimination, responding on the left key in the presence of two different stimuli (*e.g.*, cross-red, circle-green) and on the right key in the presence of all other stimuli (*e.g.*, circle-red, square-red, triangle-red, triangle-green, square-green, cross-green). The requirements for food reinforcement (*i.e.*, completion of a chain) were therefore the "identification" (*i.e.*, left-key response) of two discriminative stimuli and the "rejection" (*i.e.*, right-key response) of a variable number of stimuli. Sixty reinforcements of 3.5-sec access to mixed grain constituted a session. Sessions were conducted seven days a week, with few exceptions.

During baseline, a 10-sec timeout for errors was in effect; other durations were presented in the following order: 10, 30, 10, 0.25, 10, and 90 sec. All conditions were in effect for a minimum of 14 sessions. A no-timeout condition was briefly studied early in the experiment, but when the discriminative performance rapidly deteriorated, this condition was terminated. Total percentage of errors per session (errors/corrects plus errors) and running time (total session time minus time spent in timeout) were the major dependent variables. Within-session acquisition was evaluated by examination of the cumulative records.

Results and Discussion

Generally, timeout duration had no effect on either per cent errors or response rate. The medians and ranges of per cent errors for the last 12 sessions at each timeout duration are shown in Figure 2 for each subject. The last determination for the 10-sec duration is shown. For three of the four subjects, median per cent errors were slightly lower at the 10-sec duration than at the other durations studied. What is clearly evident, however, is a large overlap of the ranges for each subject at the various durations. Prolonged pausing occurred during five of the 12 sessions at the 90-sec timeout duration for P117. These sessions were terminated on the basis of time. This also occurred during a single session for Subjects P115 and P118 at the same duration. No systematic effect on rate of responding was found at the durations studied, other than those noted at 90 sec. Inspection of the cumulative records further revealed that varying the timeout duration had virtually no effect on the within-session acquisition of the discrimination.

The data of this experiment are similar to the results of Boren and Devine (1968), who found little difference in the effect of various timeout durations on errors in the repeated acquisition of serial-response sequences. Boren (1969) also reported no difference in error levels between timeout delays of 1 and 15 sec, while a delay-only condition (where no stimulus change occurred following an error) increased errors. Similarly, in the present experiment, a brief (0.25 sec) stimulus change associated with an error maintained a performance comparable to that found at much longer timeout durations.

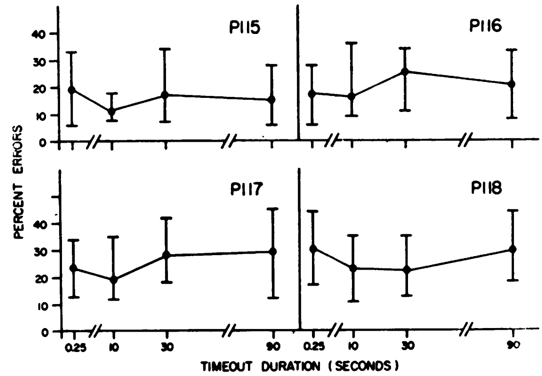

Fig. 2. Per cent errors for each subject as a function of timeout duration (in seconds). The medians and ranges for the last 12 sessions at each duration are shown.

EXPERIMENT II: EFFECTS OF EXTENDED TRAINING

In addition to the within-session error reduction normally seen in a repeated-acquisition procedure (Boren and Devine, 1968; Thompson, 1971), both Boren (1969) and Thompson (1975) reported that extended training on a single sequence of responses results in a decrease in errors on that sequence across sessions. The purpose of Experiment II was to determine whether extended training with a single set of discriminative stimuli for a left-key peck would affect the discrimination across sessions in a similar manner. Another point of interest was to determine what, if any, effects overtraining would have on the acquisition of the next discrimination.

Method

Subjects and Apparatus

The same as in Experiment I.

Procedure

The same general procedure as in Experiment I was employed with the following exception. The same discriminative stimuli for a left-key peck were arranged for three consecutive sessions. After extended training on a given set of discriminative stimuli, different stimuli for a left-key peck were chosen; the new stimuli had one of the two following characteristics: (1) neither were discriminative stimuli for a left-key peck in the previous chain (*e.g.*, triangle-circle followed by square-cross); or (2) a partial-reversal, where one of the forms that was a discriminative stimulus for a left-key peck in the previously reinforced chain was retained, but its position within the chain was reversed and a different form was substituted in its original position (*e.g.*, triangle-circle followed by square-triangle).

Results and Discussion

Generally, errors decreased as a function of sessions of extended training. Total per cent errors as a function of three sessions of extended training are shown for each subject in Figure 3 for various sets of discriminative stimuli. The stimuli are shown in the order in which they were presented. As would be expected, when both of the stimuli for a left-key peck were changed, per cent errors were highest in the first session and then decreased. The within-session distribution of errors, however, did not change with extended training in any of the subjects. For any single session, errors occurred primarily in the beginning of the session and then decreased, with the fewest occurring at the end of the session. These data are shown for P115 in the cumulative records of Figure 4. Correct responses stepped the pen. Reinforcements are shown as pips. Downward deflections of the event pen indicate error-contingent timeouts. Note that as the number of errors decreases with successive sessions of extended training, the distribution of errors across the session remained largely unchanged. Similar effects have been reported (Boren, 1969; Thompson, 1975) for the repeated acquisition of response sequences.

In the case of a partial reversal (PR, Figure 3) errors across sessions were approximately

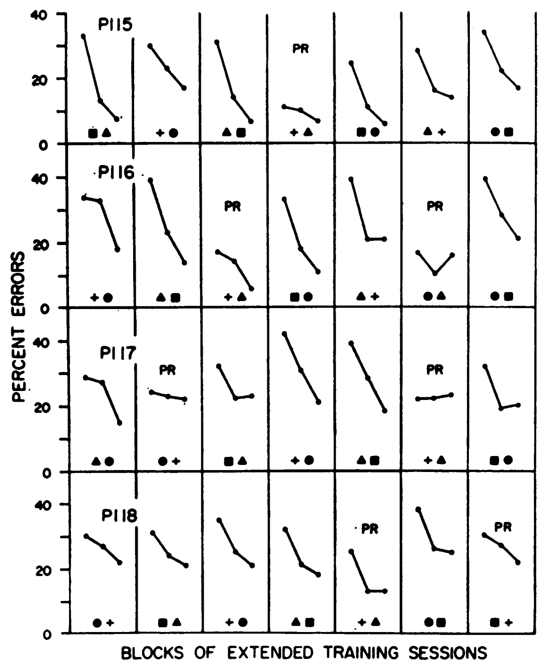

Fig. 3. Per cent errors as a function of sessions of extended training for each subject. The forms indicate the correct stimulus chain for each respective period of extended training. Partial reversals are indicated as "PR".

the same for Subject P117. For the remaining subjects, errors tended to decrease from a level comparable to the last session of the preceding series of extended-training sessions. Additionally, error levels during the first session of extended training on a partial reversal were generally lower than those that occurred during the first session when both discriminative stimuli for a left-key response were changed. This effect was most evident in Subjects P115 and P116. Had the form and color functioned as a single stimulus, a transfer effect would not be expected during the first session of extending training on a partial reversal, and errors would be approximately the same for each initial session of each block of extended-training sessions. This transfer effect therefore seems to suggest that the color and form did not function as a single stimulus, but, rather, form and color functioned as independent stimuli, which in combination, controlled responding.

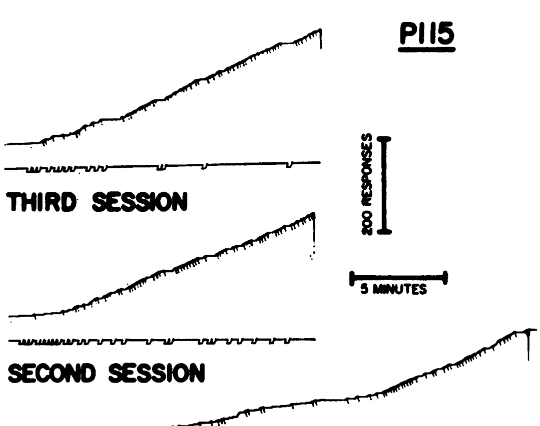

Fig. 4. Cumulative records for Subject P115 for three sessions of extended training. Correct responses stepped the response pen. Reinforcements are shown as pips. Downward deflections of the event pen indicate error-contingent timeouts.

EXPERIMENT III: TANDEM SCHEDULE EFFECTS

In the procedure of Experiments I and II, the colors functioned as block counters in the chain (Ferster and Skinner, 1957, p. 109). The conditional aspect of the procedure, however, was jointly determined by the geometric form and chain position (*i.e.*, first or second link), where chain position was marked by key color. Discriminative control, therefore, could be based on form and chain position, independently of color. In other words, to respond correctly, the subject need not use the colors as discriminative stimuli for chain position, but may use its own behavior as a stimulus (*i.e.*, response-produced stimuli). For example, the subjects' location in the chamber could function as an effective stimulus for chain position. If, following reinforcement, the subject stood slightly to the right of the center key and then, following a correct left-key peck (*i.e.*, no timeout followed the left-key response), shifted to the left of the center key, the subject would be able effectively to discriminate chain position. Discriminative control on this basis would require only that the subject was sensitive to the consequences of each response.

Thompson (1970, 1975) has shown that serial position or a subject's own behavior may control responding in a tandem schedule of repeated acquisition of response sequences. He found that, though error levels were higher in a tandem compared to a chain schedule, pigeons were able to acquire a new response sequence on a session-to-session basis. Similarly, Sidman and Rosenberger (1967) investigated several methods for teaching monkeys response sequences where the discrimination was based on serial position. The purpose of Experiment III then was to determine the extent to which colors, rather than the subjects' own behavior, controlled responding in this procedure of repeated acquisition.

Method

Subjects and Apparatus

The same as in Experiments I and II.

Procedure

The same general procedure as for Experiments I and II was employed. During this baseline condition, both colors and forms served as stimuli (as described previously). This baseline was then compared to a tandem condition where the colors marking the first and second links of the chain were absent. In the tandem condition, only white geometric forms on a black background appeared on the center key. The chain position was not signalled by color. This condition was in effect for 12 sessions, followed by a return to the chain schedule baseline.

Result and Discussion

Twelve sessions preceding and 12 sessions subsequent to the tandem condition are shown as baseline in Figure 5. Total per cent errors and running time are shown for each subject. For three of the four subjects, total errors increased in the tandem condition. The effects on running time, however, were more variable. For Subject P115, five of the 12 sessions were terminated on the basis of time, primarily because of prolonged pausing. Where the sessions were completed, session time was only slightly increased. Errors for this subject increased to 25% from a baseline median of 10%. A slight downward trend in errors across sessions can be seen in Figure 5 for this subject. For Subject P116, errors also increased in the tandem condition, from a baseline median of 15.5% to 29%. Session time, however, did not increase for this subject, with the exception of a single session that the subject failed to complete. Errors for Subject P117 increased from 16.0% to 30.5%. Though variable, running time tended to increase for this subject across sessions in the tandem condition. Error levels and session time increased only slightly for Subject P118 when the colors were removed from the chain. Median errors in the tandem condition were 27% compared to 22.5% in the baseline condition. These data seem to suggest that the colors contributed little to the discriminative performance of this particular subject.

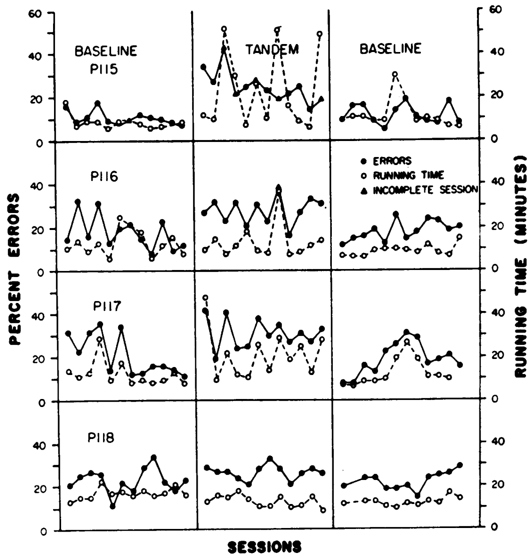

Fig. 5. Per cent errors (solid circles) and running time (open circles) for each subject for both baseline and tandem conditions.

The results of Experiment III are in agreement with the notion that reinforcement in the presence of a stimulus is a necessary but insufficient condition to ensure that a particular stimulus will acquire control over a specific behavior. For example, Reynolds (1961) demonstrated selective control by one of several stimuli that are presented in a conditional stimulus situation. In the present procedure, either colors or the subject's own behavior could function as a discriminative stimulus for chain position. For three of the subjects, errors increased in the tandem schedule condition. For these subjects, colors did function as discriminative stimuli. Error levels for P-118 did not, however, increase in the tandem condition. Additionally, the reduction in per cent errors across sessions for Subject P115 seems to indicate that performance may, in fact, come under the control of chain position, independent of color. That is, a subject may in time learn to discriminate chain position in the absence of the colors. A similar type of control has been reported for the repeated acquisition of response sequences (Sidman and Rosenberger, 1967; Thompson, 1970, 1975).

GENERAL DISCUSSION

In Experiment I, timeout duration was found to have no effect on accuracy or the within-session acquisition of the discrimination. That timeout duration did not affect accuracy may be related to the function of a timeout in acquisition. At least three possible functions of timeout have been suggested. It may function as (1) an aversive stimulus (Zimmerman and Ferster, 1963), (2) as a stimulus exerting control over switching behavior (Thompson, *in press*), and (3) as a stimulus preventing the superstitious chaining of responses (Boren, 1969).

Ferster and Appel (1961) and Zimmerman and Ferster (1963) found that with matching-to-sample performance, intermediate timeout durations produced greater accuracy than did either very short or long durations. They concluded that timeout functioned primarily to punish errors. If a timeout functioned primarily as an aversive stimulus (signalling a delay of reinforcement) the duration of the timeout might be expected to influence acquisition of the discrimination. The data of Experiment I, however, are similar to those reported by Boren and Devine (1968). In a repeated acquisition procedure, error levels were found to be invariant, independent of the duration of the timeout (1 to 240 sec). This seems to suggest that a timeout may have either an additional or different function in acquisition than it does in performance.

One possibility is that a timeout functions as a stimulus for a discriminated operant; such as exerting discriminative control over switching behavior (*cf.* Thompson, *in press*). For example, in a repeated acquisition procedure, where correct responses are required on three (or more) operanda, the timeout may function as a discriminative stimulus for switching response location. Generally, in these procedures only correct responses advance the subject through the chain (*cf.* Boren and Devine, 1968; Thompson, 1970). The stimulus conditions following a timeout are the same as those that preceded it. Since a correction procedure was also used in the present study, the stimulus change associated with an error (*i.e.*, a timeout) may have functioned as a discriminative stimulus for switching response location. However, in a procedure where three (or more) operanda are used, these "switching" responses may be either correct or incorrect. In comparison, in the present procedure only two keys were used. Therefore, following a timeout a response on the opposite key would always be correct. If the timeout functioned solely as a stimulus for switching to the other key, consecutive or perseverative errors should have occurred infrequently. Furthermore, if a subject were to respond on a single key until an error was made, and then switch to the other key, the frequency of errors within the session would be approximately equal. Since runs of incorrect responses were frequently observed to occur at the beginning of a session and the frequency of errors decreased within a session (see Figure 4, Session 1), it seems unlikely that the stimulus change associated with the timeout functioned simply to control switching behavior in the present procedure.

Boren (1969) suggested another function of timeout within a repeated acquisition procedure. As was found in Experiment I of the present study, he found that the stimulus change associated with a timeout, rather than the delay, was critical in the acquisition of the discrimination (Boren, 1969). Similarly, Hursh (1977) found that when a distinctive stimulus was presented after each correct response, both accuracy and the rate of within-session acquisition were superior in comparison to a condition where no differential stimulus change occurred. Boren proposed that the stimulus change associated with a timeout functioned primarily to prevent the superstitious chaining of responses. Though not tested directly, the timeout may have functioned similarly in the present study.

Dual control by both colors and forms has been previously reported for the multiple schedule performance of conditional discriminations (*e.g.*, Born, Snow, and Herbert, 1969). Similar results were obtained in the present study. Extended training with a single set of discriminative stimuli was found to improve acquisition of a partially reversed discrimination in Experiment II. These data indicated that the forms functioned as stimuli independent of the colors. In Experiment III, error levels for three of the four birds were found to be higher in a tandem than in a chain condition, indicating that the colors were also functioning as stimuli controlling behavior in acquisition.

The results of these experiments demonstrate that the repeated acquisition of conditional discriminations is affected by some of the same variables in the same way as the repeated acquisition of serial-response sequences. Additionally, the present experiments demonstrate that a repeated acquisition technique may be used to study transition states in complex discriminative repertoires comparable to those studied in the steady state.

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